MotionScope MV SDK

Reference Manual (32/64-bit)

Software Development Kit for Machine Vision

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1. Overview

The on-line documentation of the Machine Vision (MV) Software Development Kit (SDK) and its components is divided into the following parts:

Using the MotionScope M™ MV SDK

This section shows how to use the SDK.

MotionScope M™ MV SDK Reference

This section contains a detailed description of the SDK functions.

Appendix

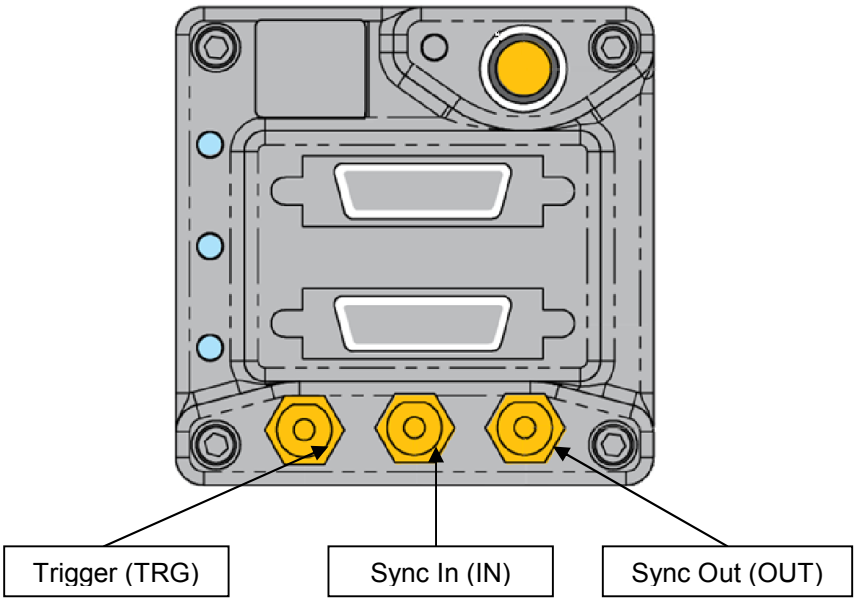
This section provides additional information about data structures, parameters and return codes.

1.1. Note about the word “Trigger”

In machine vision applications, the word “trigger” usually refers to the camera external synchronization signal (usually a square wave signal).

In this manual the word “trigger” refers to an external event (usually a single pulse) that ends the acquisition in a “circular” or “round-robin” array of buffers. The external square wave source of synchronization is referred as “Sync In”.

The MotionScope M camera has three external BNC connectors (See the image below).



1.2. Directories structure

The default installation directory of the SDK is "**C:\Program Files\IDT\\MVXSDK**". Under this directory a set of sub-directories is created:

BIN32: it contains the 32-bit files (executables and DLLs). They can be distributed with the camera and your 32-bit application.

BIN64: it contains the 64-bit versions of the driver and the utilities. They can be distributed with the camera and your 64-bit application

CFGFILES: it contains the camera configuration files for Coreco Sapera CamExpert (.CCF), National Instruments Measurement and Automation Explorer (.ICD) Matrox MIL Intellicam (.DCF) and BitFlow CiView (.R64).

DOCS: it contains the SDK documentation.

INCLUDE: it contains the SDK header files (H, CS, VB, PY) and the source code of the classes that implements the serial command protocol.

LIB: it contains the SDK lib files.

SOURCE: it contains the Visual C++ SDK examples.

1.3. Redistributable Files

This section outlines the options available to third-party vendors for distributing M camera drivers for Windows 2000/XP/Vista. The files that can be redistributed are in the BIN32, BIN64 and in the CFGFILES subdirectories of the installation directory (C:\Program Files\IDT\MVXSDK).

File	Description
MVXDriver.dll	SDK main interface driver (32 and 64-bit)
M3.CCF M5.CCF	Configuration files for Coreco Sapera CamExpert
IDT MotionScope M3.icd IDT MotionScope M5.icd	Configuration Files for NI M&A Explorer
IDT-M3-FreeRun.r64 IDT-M5-FreeRun.r64	Configuration Files for BitFlow SysReg
IDT MotionScope M3.dcf IDT MotionScope M5.dcf	Configuration Files for Matrox MIL Intellicam

1.4. Supported Frame grabbers

The frame grabbers currently supported and tested are:

- Dalsa Coreco X64 Xcelera-CL PX4.
- National Instruments PCIe-1429.
- BitFlow Karbon-CL.
- Matrox Helios/Solios.

1.5. Camera calibration file distribution

Each camera CD contains the camera calibration file (**CameraFiles** subdirectory of the CD).

The default location of the camera calibration file is the **C:\Common Files\IDT\CameraFiles** directory. If an older version of MotionStudio is installed, the default camera calibration folder is the **Windows\System32** directory.

The user may change the default directory by adding a specific key to the system registry.

HKEY_LOCAL_MACHINE\SOFTWARE\IDT\MotionProX

Then add a string value (**CalibrationFileDirectory**) containing the path to the directory where the calibration file is stored.

This registry value will override any further installation of Motion Studio.

1.6. Tools

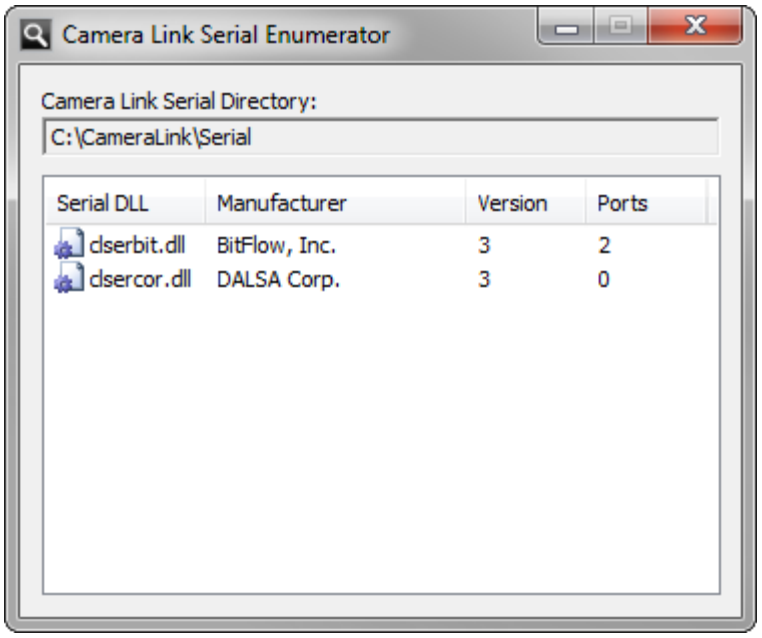
The SDK package provides two tools:

1. **CameraLink Serial Enumerator**: this utility enumerates the clserxxx.dll files installed in the computer and displays information about them. It identifies the Camera Link Serial Directory and loads the clserxxx.dll files stored in that directory.

2. **MVXControl**: the utility configures the MotionScope camera parameters and starts/stops a free run acquisition.

1.6.1. Camera Link Serial DLL Enumerator

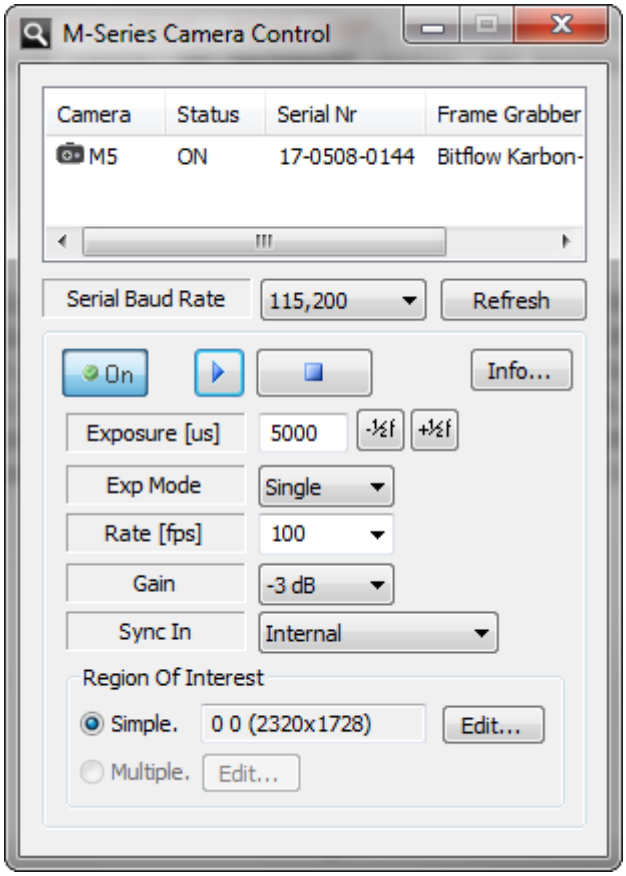
The Camera Link serial DLL Enumerator is a tool that detects and lists all the clserxxx.dll files installed on your computer in the Camera Link serial directory. For further information about the Camera Link Serial API and directory, please refer to the Camera Link AIA specifications.



1.6.2. Camera Control

The Camera Control Tool lists the M-Series cameras connected to the computer and shows a set of configuration parameters to modify.

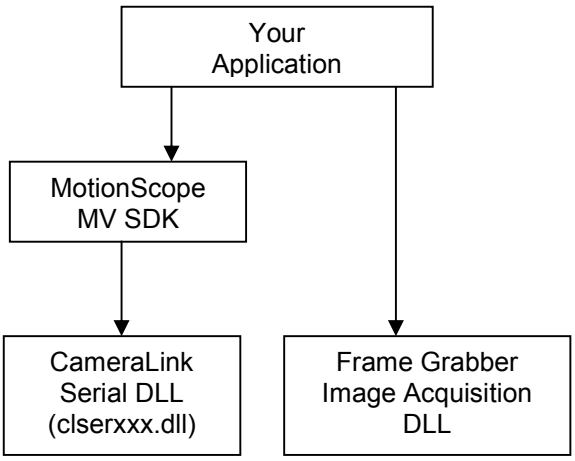
The user may open the camera, change exposure, rate, gain and ROI, as well as synchronization source. Then the camera can start acquiring the images.



2. Using the MotionScope M™ MV SDK

2.1. Overview

The MotionScope MV SDK provides a consistent programmatic interface for camera control. The figure below illustrates the software layers that support your application when using the SDK. The SDK sends camera control commands to the camera by way of the standard CameraLink “clserxxx.dll” file specified in the CameraLink standard and provided by the frame grabber vendor. For image acquisition via CameraLink your application will directly call the frame grabber vendor’s support DLL (frame grabber’s API).



As an option, the user can implement the source code to send commands to the camera via the serial port. The Include subdirectory contains some example C++ files that show how to do it (please refer to the Serial Command Protocol chapter).

2.2. Programming Languages

A C/C++ header file is included in the SDK (**MVX_API.h** file in the Include sub-directory).

Most compiled languages can call functions; you will need to write your own header/import/unit equivalent based on the C header file.

The Windows driver is a DLL (MVXDriver.dll) that may be found also in the Bin32 sub-directory (Bin64 for the 64-bit version).

MS Visual C++™: A Visual C++ 6.0 stub COFF library is provided (**MVXDriver.lib** in the Lib sub-directory); if you are using Visual C++, link to MVXDriver.lib. The DLL uses Windows standard calling conventions (_stdcall). The 64-bit version of the stub lib is **MVXDriver64.lib** in the same directory.

Borland C++ Builder™: the MVXDriver.lib file is in COFF format. Borland C++ Builder requires the OMF format. To convert the library into to OMF format, use the IMPLIB Borland tool with the following syntax: “IMPLIB MVXDriver.lib MVXDriver.dll”.

MS Visual C#: the **MvCamera.cs** file has been added to the include folder. It wraps the APIs into a C# class. Just include the file into your C# project and call the “**MvCamera**” class members.

MS Visual Basic: Visual Basic modules are included in the Include subdirectory (MVX_API.vb and MVX_API.bas).

Other compilers: the Most other compilers can create a stub library for DLLs. The DLL uses Windows standard calling conventions (_stdcall).

2.3. Load/Unload the Driver

The first call into the MV driver must be **MVLoadDriver**. Call **MVUnloadDriver** when you are finished.

2.4. Read/Write System parameters

Some configuration parameters, called system parameters, should be configured before opening a camera. The system parameters are listed below:

MVP_SYS_BAUDRATE: it controls the serial port speed (baud rate). The values are enumerated in the MV_BAUD_RATE type.

The example below shows how to set the baud rate to 57,600

```
    // Load the driver
    MVLoadDriver();

    // Set the baud rate to 57,600
    MVSeSystemParameter( MVP_SYS_BAUDRATE, MV_BAUDRATE_57600, 0
);

    // Unload the driver
    MVUnloadDriver();
```

2.5. Enumerate/Open a camera

To get the list of available cameras, call **MVEnumCameras**. The *lpszCLSerialDir* parameter may be NULL (in that case the serial DLLs are loaded from the default Camera Link Serial Directory) or a specific directory (for instance, C:\Windows\System32). Once the cameras are enumerated, use the **nCamID** field of the camera list in your call to **MVOpenCamera**. Here is a simple example of opening the first available camera:

```
    MV_ENUMITEM mvl[10];
    unsigned long nListLen = sizeof(mvl)/sizeof(MV_ENUMITEM);

    // Load the driver
    MVLoadDriver();

    // nListLen is the length of your MV_ENUMITEM array
    MVEnumCameras( NULL, &mvl[0], &nListLen );
    // nListLen is now the number of cameras available. It may
be
    // larger than your MV_ENUMITEM array length!
    if (( nListLen > 0 ) && (mvl[0].bIsOpen == FALSE ))
    {
         MV_HANDLE hCam;
         // Open the first camera in the list.
         MVOpenCamera(mvl[0].nCamID, &hCam );
         // Do something...
         ...
         // Close the camera.
         MVCloseCamera( hCam );
    }

    // Unload the driver
    MVUnloadDriver();
```

The camera list contains a unique ID which identifies each particular camera. Many developers use the unique ID to recall previous settings, or associate a meaningful name string with a camera.

2.6. Camera information

The information values that can be read from the camera are listed below:

Camera ID: it's a unique number that identifies the camera. It may change if other frame grabbers and cameras are installed.

Camera Model: the camera model (M3 or M5).

Color: it indicates if the camera is monochrome or color.

Serial Number: it's a 10 digit number that uniquely identifies the camera.

Hardware revision: the camera hardware revision

Frame Grabber Type: it shows

Sensor width and height: the sensor size in pixels

Firmware Version: the version of the firmware running in the camera.

Calibration File: it indicates if the camera calibration file is installed

Multi-ROI support: it indicates if the multiple-ROI capability is supported.

2.7. Camera Parameters

The parameters that can be configured in the camera are described below.

Exposure: The amount of time that light reaches the image sensor. It's known also as integration time.

Exposure mode: the camera can acquire one (single exposure, default mode) or two images (double exposure). In double exposure mode, the exposure of the second image is fixed and equal to the read-out time.

Period (Rate): the period is the inverse of the acquisition rate.

Gain: the camera has four sensor gain values. Larger values of gain will produce brighter images.

Pixel Gain: M cameras acquire 10 bit images. The user may select to read 8 bit out of 10 in three different ways: upper bits (default), middle bits, or lower bits.

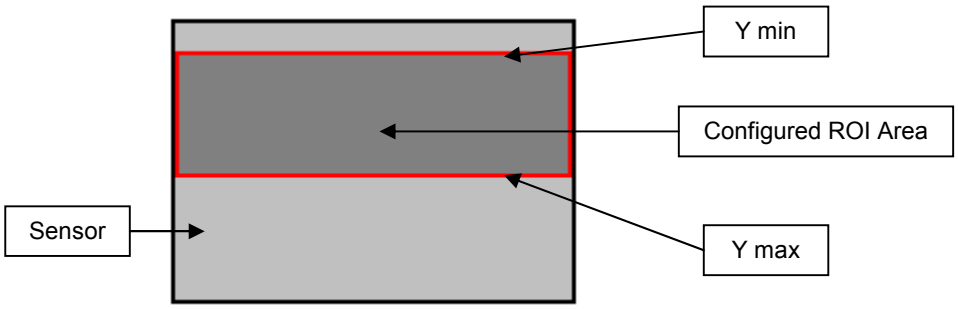
Record Mode: the camera may stream the images to an array of buffers. If the mode is set to normal, the camera fills the buffers and stops streaming. If the mode is set to circular, the camera grabs round-robin into the buffers array, until an event trigger stops it. See the frame grabber documentation to configure a "circular" or "round-robin" acquisition in an array of buffers.

Sync In Configuration: the camera sync source can be the internal camera clock or an external wave form. If the source is external the acquisition of each frame can be done on the leading edge (edge-high), on the falling edge (edge-low), during the high level (pulse-high) or during the low level (pulse-low) of the sync signal.

Region of Interest (ROI): see the topics below.

2.8. Region of Interest (ROI)

The M-series cameras support the region of interest feature (ROI). The sensor supports vertical windowing and the user can set the start row (Y min) and the stop row (Y max). See the picture below.



The picture shows the full sensor area (black rectangle) and the ROI area configured by the user (red rectangle).

2.9. Multiple region of Interest (MROI)

M3 cameras with firmware version 8 and above allow multiple region of interest. The user may select single rows from the sensor with a special Boolean table.

The table is an array of 1024 bytes; if a value is 0, the corresponding row is skipped, otherwise it is selected. The example below shows how to select rows 0, 2, 4, etc and acquire an image with height = 512.

```
unsigned char abyTbl[1024];
int i,j;

// prepare the table
for(i=0,j=0; i<512; i++)
{
     abyTbl[j++] = 1;
     abyTbl[j++] = 0;
}

// change to multi roi mode
MVSetParameter(MVP_ROI_MODE, MV_ROI_MULTI, 0);

// send the table
MVSetParameter(MVP_ROI_TABLE, (unsigned long)&abyTbl[0], 0);
```

The user may select a “simple” ROI or a “multiple” ROI with the MVP_ROI_MODE parameter. Then, if the ROI mode is set to MV_ROI_MULTI, the table will be set, as in the example above. If the mode is set to MV_ROI_SIMPLE, the user will set the MVP_ROI_Y_MIN and MVP_ROI_Y_MAX parameters.

Each time the ROI mode is changed, the table or the Y min and Y max parameters need to be set.

Multiple ROI is not currently supported by M5 cameras.

2.10. Camera Commands

Once the camera parameters are configured the user can send the camera the following commands:

MVCMD_RECORD: the camera starts streaming images.

MVCMD_STOP: the camera stops streaming images.

MVCMD_TRIGGER: the camera receives a software trigger and ends the circular acquisition.

MVCMD_RESET: the camera is reset.

NOTE: most of the camera parameters can be changed while the camera is streaming.

2.11. Background, Pixel Sensitivity and shutter line

The images acquired from the M cameras require some post-processing correction because the architecture of the CMOS sensor introduces noise and non uniformity. To reduce those effects a calibration file is produced and distributed with the camera.

In addition to this, M5 camera images may have a horizontal line, called “shutter line”.

2.11.1. Background

Background correction is required because the images acquired with the lens cap on are not perfectly black. The background images are stored in the calibration file and have been taken in different operating conditions.

The images should be subtracted to the acquired images to remove the dark background. Then the pixel should be rescaled to the current range like in the formulas below:

nPixel = nPixel – nBkg

nPixel = (nPixel * 256) / (256 – nBkg)

The current value of index of the background buffer is returned with a call to MVGetParameter with the argument **MVP_BKG_INDEX**. The parameter is read-only. The value should be stored somewhere after the acquisition and used in a subsequent call to MVImageCorrectData for the correction of background.

The example below shows how to correct the background on an image buffer. The buffer pBkg has been previously acquired with the camera lens cap on.

```
void CorrectBackground(unsigned char *pImg,
                       unsigned char *pBkg,
                       int nImgSize)
{
     int i, nData, nBkg;

     for (i=0; i<nImgSize; i++)
     {
          nData = *pImg;
          nBkg = *pBkg++;

          if(nBkg>=nData) nData = 0;
          else
          {
               // rescale for background
               nData = (nData * 256)/(256 - nBkg);
               if( nData>255 ) nData=255;
          }
          *pImg++ = (unsigned char)nData;
     }
}
```

2.11.2. Background (M5 camera with Orion II sensor)

The Orion II sensor has 32 dark columns that can be used to reduce the horizontal temporal noise. Not all the 32 column value can be used for that purpose:

- Columns 0 to 11: dark columns values from left side of the sensor.
- Columns 12 to 23: dark columns from right side of the sensor.

The procedure for the subtraction of the dark columns and the background is shown below.

1. Extract 2288 image values from the 2320 row buffer.

2. Compute the average values of dark columns on left and right side of the sensor: nDKL and nDkR. Skip the columns that are closer to the visible part of the sensor (10, 11, 12 and 13).

   nDkL = avg(img[0],img[1],img[2],img[3],img[4],img[5],img[6],img[7],img[8],img[9])

   nDkR = avg(img[14],img[15],img[16],img[17],img[18],img[19],img[10],img[21],img[22],img[23])

3. To avoid that the image values after background correction go “below zero” when we apply dark columns we need to add a constant offset to the image. The same value is included in background images, and then it is removed when the background is applied. Use the values of nDkL and nDkR to compute the value of nDkVal in each position, and then subtract dark column and background. After dark column and background subtraction the value is multiplied by a constant gain (1060). The code below is applied to each row of the image.

```
    for (j=0; j<W; j++)
    {
        nDkVal = nDkL + j * (nDkR - nDkL) / (MaxW - 1);

        Pix = IMG[j] + nOffs - nDkVal;
        Bkg = BKG[nCol];

        Pix = Pix - Bkg;

        Pix = (Pix * nGain)>>10;
        if(Pix>255) Pix = 255;
        PIX[i] = Pix;
    }

Where:
    IMG = source image row buffer
    BKG = background row buffer
    PIX = destination image row buffer
    nOffs = 48
    nGain = 1060
    nMaxW = 2288
```

2.11.3. Pixel Sensitivity Correction (PSC)

PSC images are acquired with a uniform light source and stored win the calibration file. They are used to compensate the non uniformity in different areas of the sensor (especially borders). PSC images are made of 16 bit coefficients that are multiplied to the pixel values. A value of 1024 indicates that the pixel does not change. The formula below shows how to compensate the value “nPixel”.

nPixel = (nPixel * nCoeff) >> 10;

The current value of index of the PSC buffer is returned with a call to MVGetParameter with the argument **MVP_PSC_INDEX**. The parameter is read-only. The value should be stored somewhere after the acquisition and used in a subsequent call to MVImageCorrectData for the correction of PSC.

The example below shows how to correct the pixel sensitivity on an image buffer. We assume that the buffer pPSC has been previously acquired without the camera lens and with a source of constant light.

```
void CorrectPixelSensitivity(unsigned char *pImg,
                             unsigned char *pPsc,
                             int nImgSize)
{
     int i, nData, nPsc;

     for (i=0; i<nImgSize; i++)
     {
          nData = *pImg;
          nPsc = *pPsc++;

          nData = ((nData*nPsc)>>10);
          if( nData>255 ) nData=255;

          *pImg++ = (unsigned char)nData;
     }
}
```

2.11.4. Shutter line (M5 camera)

The “shutter line” is a bright horizontal line that appears in M5 images only if the exposure and the acquisition period values satisfy the formula below:

$$T_{exp} + T_{ro} > T$$

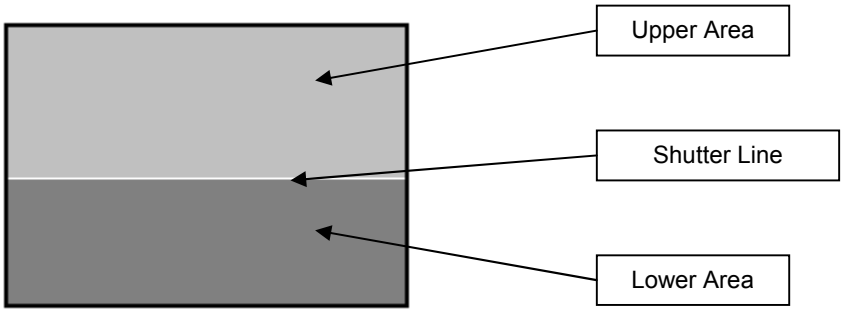
Where:

T_{exp} = exposure time

T_{ro} = Readout time. It’s the inverse of the maximum rate (at full resolution is about 5.88 ms).

T = period.

The difference between the average intensity of the upper and lower areas of the image is about 3 or 4 counts. The lower area is usually darker (see the picture below). In cameras with Orion II sensor there is no difference in intensity between upper and lower areas.



The current value of the shutter line position is returned with a call to MVGetParameter with the argument **MVP_SHUTTER_LINE**. The parameter is read-only. If the shutter line is not present and the image does not need correction, the MVGetParameter routine returns MV_E_NO_LINE.

The value should be stored somewhere after the acquisition and used in a subsequent call to MVImageCorrectData for the correction.

2.12. Automatic Correction of the image

The values read before the acquisition with the parameters arguments MVP_BKG_INDEX, MVP_PSC_INDEX and MVP_SHUTTER_LINE can be used to automatically correct the acquired images.

The procedure is below.

1. When the camera is online and before starting to acquire, call the MVGetParameter with the argument MVP_BKG_INDEX to read the background buffer index (nBKG), the argument MVP_PSC_INDEX to read the PSC buffer index (nPSC) and MVP_SHUTTER_LINE to read the shutter line position if the camera is an M5 (nSHL). Then store the nBKG, nPSC and nSHL values in variables that will be used later.

2. Open the image correction engine (**MVImageOpen**) with the camera serial number and sensor model as arguments. These values are required to identify the camera calibration file and read the correct background and PSC buffers. The camera can be disconnected when this routine is called.

3. Call the **MVImageCorrectData** routine with the values of nBKG, nPSC and nSHL, the dimensions of the input image, the correction flag and the shutter line offset. The correction flag can be a combination of **MV_IMGC_BKG** bit (for background), **MV_IMGC_PSC** bit (for PSC) and **MV_IMGC_SHL** bit (for shutter line). The value **MV_IMGC_ALL** includes all the above values. A positive offset will be added to the area of the image that is below the shutter line, a negative offset will be subtracted to the same area.

4. Close the correction engine with a call of **MVImageClose**.

NOTE about M5 camera with Orion II sensor: Orion II sensor has 32 dark columns. When the MVImageCorrectData routine is called, the input buffer width is 2320 pixels but the image width parameter must be 2288. The routine automatically extracts the 32 dark columns from the input buffer and generates a 2288 pixels wide output image.

2.13. Manual correction of the image

If the user wants to manually correct the images, the SDK provides a routine that returns the background and pixel sensitivity buffers.

The procedure is below.

1. When the camera is online and before starting to acquire, call the MVGetParameter with the argument MVP_BKG_INDEX to read the background buffer index (nBKG), the argument MVP_PSC_INDEX to read the PSC buffer index (nPSC) and MVP_SHUTTER_LINE to read the shutter line position if the camera is an M5 (nSHL). Then store the nBKG, nPSC and nSHL values in variables that will be used later.

2. Open the image correction engine (**MVImageOpen**) with the camera serial number and sensor model as arguments. These values are required to identify the camera calibration file and read the correct background and PSC buffers. The camera may be disconnected when this routine is called.

3. Allocate two buffers, one for the background and one for the PSC. The background buffer size is W x H, where W is the sensor width and H is the sensor height (the values can be read from the camera). The PSC buffer size is 2 x W x H.

4. Call the **MVImageGetCorrectionBuffer** routine two times. The first time use the value of nBKG as index and **MV_IMGC_BKG** as correction flag, to read the background buffer. Then use nPSC as index and **MV_IMGC_PSC** as correction flag, to read the PSC data.

5. Write some lines of code to correct the image for background (see topic 2.10.1 or 2.10.2), PSC (see topic 2.10.3) and shutter line.

6. Close the correction engine with a call of **MVImageClose**.

2.14. Read the camera status

A routine has been introduce to read the camera status (MVGetStatus). The returned status may be 0 if the camera is in idle mode or 1 if it's busy streaming. The routine may be used to detect whether an acquisition is done.

2.15. 64 Bit Programming

One of the main issues in migrating software from 32 bit to 64 bit platforms is the size of types.

An "int" and a "long" are 32-bit values in 64-bit Windows operating systems. For programs that you plan to compile for 64-bit platforms, you should be careful not to assign pointers to 32-bit variables. Pointers are 64-bit on 64-bit platforms, and you will truncate the pointer value if you assign it to a 32-bit variable.

In the MV SDK all the parameters are 64 bit values, but for most of them the most significant 32-bit part is set to 0. You should be careful if you set multiple ROI because the parameter is a table. The example below shows how to read and write the multiple ROI table in a 64-bit program.

```
unsigned char abyTbl[1024];
unsigned long *pTbl = (unsigned long*)&abyTable[0];
unsigned long nLoValue, nHiValue;

// read the table
MVGetParameter(MVP_ROI_TABLE, pTbl, NULL);

// change 1 item of the table
abyTbl[0] = 0;

// write the table
nLoValue = (unsigned long)&abyTbl[0];
nHiValue = (unsigned long)((&abyTbl[0])>>32);
MVSetParameter(MVP_ROI_TABLE, nLoValue, nHiValue);
```

3. MotionScope M™ MV SDK Reference

3.1. Initialization Functions

3.1.1. Overview: Initialization functions

Initialization functions allow the user to initialize the driver, enumerate the available cameras, open and close them.

MVGetVersion returns the DLL version numbers.

MVLoadDriver loads the driver and initializes it.

MVUnloadDriver unloads the driver.

MVGetSystemParameter reads one of the system parameters

MVSetSystemParameter configures one of the system parameters

MVEnumCameras enumerates the M-Series cameras connected to the computer.

MVOpenCamera opens a camera.

MVCloseCamera closes a camera previously open.

3.1.2. MVGetVersion

MV_ERROR MVGetVersion (**unsigned short** **pVerMajor*, **unsigned short** **pVerMinor*)

Return values

MV_SUCCESS if successful, otherwise

MV_E_GENERIC_ERROR if the version numbers could not be extracted from the driver.

Parameters

pVerMajor

Specifies the pointer to the variable that receives the major version number

pVerMinor

Specifies the pointer to the variable that receives the minor version number

Remarks

This function must be called to retrieve the DLL version.

See also:

3.1.3. MVLoadDriver

MV_ERROR MVLoadDriver (void)

Return values

MV_SUCCESS if successful, otherwise

MV_E_GENERIC_ERROR if any error occurs during the initialization.

Parameters

None

Remarks

The routine loads the driver DLL and initializes it. It must be called before any other routine, except **MVGetVersion**. If any error occurs, the routine returns MV_E_GENERIC_ERROR.

See also: **MVUnloadDriver**

3.1.4. MVUnloadDriver

void MVUnloadDriver (void)

Return values

None

Parameters

None

Remarks

This function must be called before terminating the application. This function frees any memory and resource allocated by the driver and unloads it.

See also: **MVLoadDriver**

3.1.5. MVGetSystemParameter

MV_ERROR MVGetSystemParameter (**MV_PARAM** *nParamKey*, **unsigned long** ***pLoValue,* **unsigned long** ***pHiValue*)

Return values

MV_SUCCESS if successful, otherwise

MV_E_INVALID_ARGUMENTS, if one of the arguments is not valid.

MV_E_NOT_SUPPORTED, if the nParamKey is not supported.

Parameters

nParamKey

Specifies which parameter the function returns

pLoValue

Specifies the pointer to the variable that receives the LS part of the parameter's value

pHiValue

Specifies the pointer to the variable that receives the MS part of the parameter's value

Remarks

This function reads a system parameter.

See also: MVSetSystemParameter

3.1.6. MVSetSystemParameter

MV_ERROR MVSetSystemParameter (**MV_PARAM** *nParamKey*, **unsigned long** *nLoValue,* **unsigned long** *nHiValue*)

Return values

MV_SUCCESS if successful, otherwise

MV_E_INVALID_VALUE, if the parameter value is not valid

MV_E_NOT_SUPPORTED, if the nParamKey is not supported.

Parameters

nParamKey

Specifies which parameter the function sets.

nLoValue

Specifies the LS part of the parameter's value

nHiValue

Specifies the MS part of the parameter's value

Remarks

This function writes a system parameter.

See also: **MVGetSystemParameter**

3.1.7. MVEnumCameras

MV_ERROR MVEnumCameras (**const char** ***lpszCLSerialDir**, **PMV_ENUMITEM** *pItemList*, **unsigned long** ***pItemNr**)

Return values

MV_SUCCESS if successful, otherwise

MV_E_INVALID_ARGUMENTS, if any of the parameters is not valid.

Parameters

lpszCLSerialDir

Specifies the camera Link Serial Directory

pItemList

Specifies the pointer to an array of MV_ENUMITEM structures

pItemNr

Specifies the pointer to the variable that receives the number of detected cameras

Remarks

The routine enumerates the active cameras and fills the **MV_ENUMITEM** structures with information about them. The driver loads the clserxxx.dll files detected in the *lpszCLSerialDir* directory or in the default Camera Link Serial directory if *lpszCLSerialDir* is NULL. This routine must be called before **MVOpenCamera** to find out which cameras are available. The pItemNr variable must specify the number of structures in the pItemList array and receives the number of enumerated cameras.

See also: **MVOpenCamera**

3.1.8. MVOpenCamera

MV_ERROR MVOpenCamera (**unsigned long** *nCameraId*, **MV_HANDLE*** *pHandle*)

Return values

MV_SUCCESS if successful, otherwise

MV_E_INVALID_CAMERA_ID, if the camera ID is not valid.

MV_E_CAM_ALREADY_OPEN, if the camera is already open.

Parameters

nCameraId

Specifies the ID of the camera to be opened

pHandle

Specifies the pointer to the variable that receives the camera handle

Remarks

The routine opens the camera with the nCamID identifier. The value can be retrieved by calling the **MVEnumCameras** routine (see the MV_ENUMITEM structure).

See also: **MVCloseCamera**

3.1.9. MVCloseCamera

MV_ERROR MVCloseCamera (**MV_HANDLE** *hCamera*)

Return values

MV_SUCCESS if successful, otherwise

MV_E_INVALID_HANDLE, if the camera handle is not valid.

Parameters

hCamera

Specifies the handle to an open camera

Remarks

Closes an open Camera

See also: **MVOpenCamera**

3.2. Configuration Functions

3.2.1. Overview: Configuration functions

The configuration functions allow the user to configure the camera.

MVGetCameraInfo gets information from the camera, such as camera model, serial number, sensor size, etc.

MVGetParameterAttribute gets the parameters attributes (minimum and maximum values).

MVGetParameter gets a parameter from the camera.

MVSetParameter sets a camera parameter.

3.2.2. MVGetCameraInfo

MV_ERROR MVGetCameraInfo (**MV_HANDLE** *hCamera*, **MV_INFO** *nInfoKey*, **unsigned long** **pLoValue,* **unsigned long** **pHiValue*)

Return values

MV_SUCCESS if successful, otherwise

MV_E_INVALID_HANDLE, if the camera handle is not valid.

MV_E_INVALID_ARGUMENTS, if one of the arguments is not valid.

MV_E_NOT_SUPPORTED, if the nInfoKey is not supported.

Parameters

hCamera

Specifies the handle to an open camera

nInfoKey

Specifies which parameter the function has to return

pLoValue

Specifies the pointer to the variable that receives the LS part of the info value

pHiValue

Specifies the pointer to the variable that receives the MS part of the info value

Remarks

This function returns camera specific information, such as camera model and serial number. See the **Appendix B** for a list of all the available nInfoKey values.

See also:

3.2.3. MVGetParameterAttribute

MV_ERROR MVGetParameterAttribute (**MV_HANDLE** *hCamera*, **MV_PARAM** *nParamKey*, **unsigned long** **pMinValue,* **unsigned long** **pMaxValue*)

Return values

MV_SUCCESS if successful, otherwise

MV_E_INVALID_HANDLE, if the camera handle is not valid.

MV_E_INVALID_ARGUMENTS, if one of the arguments is not valid.

MV_E_NOT_SUPPORTED, if the nParamKey is not supported.

Parameters

hCamera

Specifies the handle to an open camera

nParamKey

Specifies which parameter the function returns.

pMinValue

Specifies the pointer to the parameter's minimum value.

pMaxValue

Specifies the pointer to the parameter's maximum value.

Remarks

This function reads the parameter’s minimum and maximum values.

See also: MVGetParameter

3.2.4. MVGetParameter

MV_ERROR MVGetParameter (**MV_HANDLE** *hCamera*, **MV_PARAM** *nParamKey*, **unsigned long *** *pLoValue,* **unsigned long *** *pHiValue*)

Return values

MV_SUCCESS if successful, otherwise

MV_E_INVALID_HANDLE, if the camera handle is not valid.

MV_E_INVALID_ARGUMENTS, if one of the arguments is not valid.

MV_E_NOT_SUPPORTED, if the nParamKey is not supported.

Parameters

hCamera

Specifies the handle to an open camera

nParamKey

Specifies which parameter the function returns

pLoValue

Specifies the pointer to the variable that receives the LS part of the parameter's value

pHiValue

Specifies the pointer to the variable that receives the MS part of the parameter's value

Remarks

This function reads a parameter from the camera.

See also: MVSetParameter

3.2.5. MVSetParameter

MV_ERROR MVSetParameter (**MV_HANDLE** *hCamera*, **MV_PARAM** *nParamKey*, **unsigned long** *nLoValue,* **unsigned long** *nHiValue*)

Return values

MV_SUCCESS if successful, otherwise

MV_E_INVALID_HANDLE, if the camera handle is not valid.

MV_E_INVALID_ARGUMENTS, if one of the arguments is not valid.

MV_E_NOT_SUPPORTED, if the nParamKey is not supported.

MV_E_INVALID_VALUE, if the parameter value is not valid

Parameters

hCamera

Specifies the handle to an open camera

nParamKey

Specifies which parameter the function sets.

nLoValue

Specifies the LS part of the parameter's value

nHiValue

Specifies the MS part of the parameter's value

Remarks

This function writes a parameter to the camera.

See also: **MVGetParameter**

3.3. Camera Control Functions

3.3.1. Overview: Camera Control functions

The camera control functions allow the user to send commands to the camera and retrieve the pointers to background and pixel sensitivity correction frames.

MVSendCommand reads sends a specific command to the camera.

MVGetStatus returns the camera current status.

3.3.2. MVSendCommand

MV_ERROR MVSendCommand (**MV_HANDLE** *hCamera,* **MV_COMMAND** *nCmdKey*, **unsigned long** *nLoParam,* **unsigned long** *nHiParam*)

Return values

MV_SUCCESS if successful, otherwise

MV_E_INVALID_HANDLE, if the camera handle is not valid.

MV_E_NOT_SUPPORTED, if the command key is not supported.

Parameters

hCamera

Specifies the handle to an open camera

nCmdKey

Specifies the command code

nLoParam

Specifies the LS part of the optional command parameter

nHiParam

Specifies the MS part of the optional command parameter

Remarks

This function sends a command to the camera. For a list of the commands please refer to the Appendix.

See also:

3.3.3. MVGetStatus

MV_ERROR MVGetStatus (**MV_HANDLE** *hCamera,* **unsigned long** *pnStatus*)

Return values

MV_SUCCESS if successful, otherwise

MV_E_INVALID_HANDLE, if the camera handle is not valid.

MV_E_INVALID_ARGUMENTS, if input parameters are not valid.

Parameters

hCamera

Specifies the handle to an open camera

pnStatus

Specifies the point to the variable where the status will be stored

Remarks

This function returns the camera current status (0: idle, 1:busy)

See also:

3.4. Image Correction Functions

3.4.1. Overview: Image Corrections functions

The image correction routines allow the user to correct the images when the camera is offline.

MVImageOpen open the image correction engine.

MVImageClose closes and image correction engine previously open.

MVImageCorrectData corrects the image with background data, pixel sensitivity data and removes the shutter line. It also compensates the difference of intensity of upper and lower areas of the image when the shutter line is present.

MVImageGetCorrectionBuffer returns a buffer of Background or PSC data.

3.4.2. MVImageOpen

MV_ERROR MVImageOpen (**unsigned long** *nSerialNumber,* **unsigned long** *nSnsModel,* **MV_IMG_HANDLE** **pHandle*)

Return values

MV_SUCCESS if successful, otherwise

MV_E_INVALID_ARGUMENTS, if the pointer to the buffer is not valid.

Parameters

nSerialNumber

Specifies the serial number of the camera which acquired the images

nSnsModel

Specifies the sensor model of the camera which acquired the images

pHandle

Specifies the pointer to a variable that receives the handle to the correction engine

Remarks

This function opens an image correction engine and returns a handle.

See also: **MVImageClose**

3.4.3. MVImageClose

MV_ERROR MVImageClose (**MV_IMG_HANDLE** *hImage*)

Return values

MV_SUCCESS if successful, otherwise

MV_E_INVALID_HANDLE, if the camera handle is not valid.

Parameters

hImage

Specifies the handle to an open image engine

Remarks

This function closes an image correction engine previously open.

See also: **MVImageOpen**

3.4.4. MVImageCorrectData

MV_ERROR MVImageCorrectData (**MV_IMG_HANDLE** *hImage,* **void*** *pDataBufIn,* **void*** *pDataBufOut,* **unsigned long** *nBkgIndex,* **unsigned long** *nPscIndex,* **unsigned long** *nShlPos,* **unsigned long** *nRoiXo,* **unsigned long** *nRoiYo,* **unsigned long** *nRoiWidth,* **unsigned long** *nRoiHeight,* **unsigned long** *nCorrectionFlag,* **int** *nShlOffset*)

Return values

MV_SUCCESS if successful, otherwise

MV_E_INVALID_HANDLE, if the camera handle is not valid.

MV_E_INVALID_ARGUMENTS, if the input arguments are not valid.

Parameters

hImage

Specifies the handle to an open image correction engine

pDataBufIn

Specifies the pointer to the input data buffer

pDataBufOut

Specifies the pointer to the output data buffer

nBkgIndex

Specifies the index of the background image to be used for the correction

nPscIndex

Specifies the index of the PSC image to be used for the correction

nShlPos

Specifies the position of the shutter line

nRoiXo, nRoiYo

Specifies the Origin coordinates of the input image ROI

nRoiWidth, nRoiHeight

Specifies the dimensions of the input image ROI

nCorrectionFlag

Specifies the correction flag

nShlOffset

Specifies the offset that is added (if positive) or subtracted (if negative) to the area of the image that is below the shutter line.

Remarks

This function corrects the image with background and pixel sensitivity data and removes the shutter line. It also compensates the difference of intensity of upper and lower areas of the image when the shutter line is present.

The operations are selected with the bits of the nCorrectionFlag variable (MV_IMGC_BKG for background, MV_IMGC_PSC for PSC and MV_IMGC_SHL for shutter line) and with the value of the nShlOffset. Other input parameters are the

background index, the PSC index, and the shutter line position. Those parameters have been read from the camera before the acquisition. If the camera model is M5 and the shutter line position is inside the image, the image can be also corrected with the shutter line offset. If the offset is positive it will be added to the area of the image that is below the shutter line (lower area). If the offset is negative it will be subtracted to the same area. If the offset is zero, no correction will be done.

See also: MVImageOpen, MVImageClose

3.4.5. MVImageGetCorrectionBuffer

MV_ERROR MVImageGetCorrectionBuffer (**MV_IMG_HANDLE** *hImage,* **unsigned long** *nIndex,* **unsigned long** *nCorrectionFlag,* **void*** *pDataBuf,* **unsigned long** *nBufSize*)

Return values

MV_SUCCESS if successful, otherwise

MV_E_INVALID_HANDLE, if the camera handle is not valid.

MV_E_INVALID_ARGUMENTS, if the input arguments are not valid.

MV_E_NO_DATA, if the correction data Is not available

MV_E_BUF_TOO_SMALL, if the output buffer is too small

Parameters

hImage

Specifies the handle to an open image correction engine

nIndex

Specifies the index of the correction data

nCorrectionFlag

Specifies the type of buffer to copy (MV_IMGC_BKG or MV_IMGC_PSC)

pDataBuf

Specifies the pointer to the output data buffer

nBufSize

Specifies the size in bytes of the data buffer

Remarks

This function copies to the pDataBuf buffer the correction data specified by the nIndex value and the nCorrectionFlag (MV_IMGC_BKG for background data, MV_IMGC_PSC for PSC data). The data may be either background or pixel sensitivity correction data. If the data is not available or the buffer size is too small the routine returns an error code.

4. Serial Command Protocol

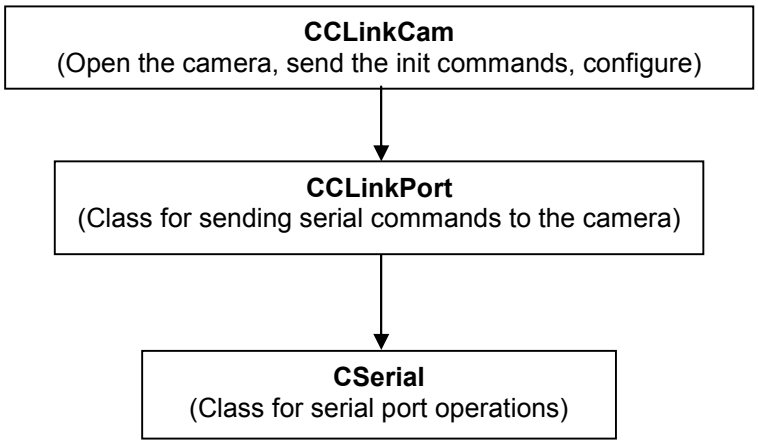
4.1. Overview

The serial command protocol is implemented in the C++ classes contained in some source code files in the “Include” directory of the SDK:

CamRegisters.h: header file that contains the definitions of internal camera registers.

CLinkPort.cpp, CLinkPort.h: files that implement the CCLinkPort class. It contains all the information for reading the camera EEPROM information, configuring the camera registers, and sending camera commands. In the same file, the CSerial class is used to include the base serial operations (Open, close, write, read, flush).

CCLinkCam.cpp, CCLinkCam.h: files that implement the CCLinkCamera class. It contains all the information to identify a camera, initialize it and start the configuration.


CCLinkCam
(Open the camera, send the init commands, configure)
CCLinkPort
(Class for sending serial commands to the camera)
CSerial
(Class for serial port operations)

The user should provide routines from the base serial port operations (Open, Close, Read, Write, Flush, Get-Baud-Rates and Set-Baud-Rate). The code will be included in the CSerial class.

4.2. Base Routines: read and write registers

The camera internal registers are read and written with the protocol implemented in the routines below.

```
// Read register
int ReadRegister(SER_HANDLE hSerial, unsigned char byAdd,
unsigned char *pbData)
{
   unsigned long dwSize;
   unsigned char abyBuf[2];
   int nRet = -1;
   //
   abyBuf[0] = 0x01 | 0x00 | 0x00 | (byAdd & 0xf) << 1;
   abyBuf[1] = 0x01 | 0x40 | 0x20 | ((byAdd >> 4) & 0xf) << 1;
   dwSize = 2;
   FlushPort(hSerial);
   if(SerialWrite(hSerial, (char*)abyBuf, &dwSize, 100)==0)
   {
      dwSize = 1;
      nRet = SerialRead(hSerial, (char*)pbData, &dwSize, 100);
   }
   return nRet;
}

// Write register
int CCLinkPort::WriteRegister(SER_HANDLE hSerial, unsigned char
byAdd, unsigned char byData)
{
   unsigned long dwSize = 4;
   unsigned char abyBuf[4];
   abyBuf[0] = 0x01 | 0x00 | 0x00 | (byAdd & 0xf) << 1;
   abyBuf[1] = 0x01 | 0x80 | 0x20 | ((byAdd >> 4) & 0xf) << 1;
   abyBuf[2] = 0x01 | 0x00 | 0x00 | (byData & 0xf) << 1;
   abyBuf[3] = 0x01 | 0x00 | 0x20 | ((byData >> 4) & 0xf) << 1;
   return SerialWrite(hSerial, (char*)abyBuf, &dwSize, 100);
}

// Write register block
int CCLinkPort::WriteRegisterBlock(SER_HANDLE hSerial, unsigned
char byAdd, unsigned char *pbyData, int nSize)
{
   unsigned char abyBuf[8192];
   unsigned long dwSize;
   int i;

   byAdd |= 0x80;
   abyBuf[0] = 0x01 | 0x00 | 0x00 | (byAdd & 0xf) << 1;
   abyBuf[1] = 0x01 | 0x80 | 0x20 | ((byAdd >> 4) & 0xf) << 1;
   for( i=0; i<nSize; i++ )
   {
      abyBuf[i*2+2] = 0x01|0x00|0x00|(pbyData[i] & 0xf) << 1;
      abyBuf[i*2+3] = 0x01|0x00|0x20|((pbyData[i] >> 4)&0xf)<<1;
   }
   dwSize = 2*nSize + 2;
   return SerialWrite(hSerial, (char*)abyBuf, &dwSize, 500);
}
```

4.3. Read camera information

The camera information is stored in a VENDOR_INFO structure inside the camera EEPROM. The EEPROM can be read via the GetVendorInfo routine in the CLinkPort.cpp file.

```
typedef struct
{
    unsigned short nSize;
    char szSignature[4];
    unsigned long nSerial;
    unsigned char bColor;
    unsigned short nSnsRev;
    unsigned short nReserved1;
    unsigned short nRevision;
    unsigned short nModel;
    unsigned short nReserved2;
    unsigned short anDACs0[20];
    unsigned short anDACs1[20];
    unsigned short anDACs2[20];
    unsigned short anDACs3[20];
    unsigned short nClock;
    unsigned short nExtraRows;
    unsigned short nRCC;
    unsigned short nReserved3;
    unsigned short nReserved4;
    unsigned short nExpSteps;
    unsigned short nReserved5;
    unsigned short nRegRp1;
    unsigned short nRegRp2;
    unsigned short nRegRp3;
} VENDOR_INFO, *PVENDOR_INFO;
```

szSignature: a four character string that contains “VINF”

nSerial: the camera serial number

bColor: 1 if the camera is color, otherwise 0.

nSnsRev: 0 for M3 and M5 cameras with Orion I sensor, 1 or above for M5 cameras with Orion II sensor.

nRevision: the hardware revision.

nModel: 5 for M3 camera, 7 for M5 camera.

anDACs0, 1, 2, 3: DACs set for gain 0, 1, 2 and 3.

nClock: the camera internal clock in MHz * 100.

nExtraRows: the camera extra rows (used for internal calculations)

nRCC: the camera row clocks count (used for internal calculations)

nExpSteps: the camera exposure steps (used for internal calculations)

nRegRp1, 2, 3: internal registers for M3 camera.

The routine used to read the vendor info structure is shown below.

```
int CCLinkPort::GetVendorInfo(SER_HANDLE hSerial, PVENDOR_INFO
pInfo)
{
   unsigned char abyInfo[512] = {0};
   PVENDOR_INFO pI = (PVENDOR_INFO)abyInfo;
   unsigned long dwAdd=0,dwSize=512;
   char szErrText[256]="";
   unsigned long nErrLen=256;
   int nRet = CL_ERR_GENERIC;
   //
   FlushPort(hSerial);
   WriteRegisterBlock(hSerial,CR_SP_COMM_BUFF, &dwAdd, 4);
   WriteRegisterBlock(hSerial,CR_SP_COMM_BUFF, &dwSize, 4);
   if( WriteRegister(hSerial,CR_SP_COMM,
CR_SP_COMM_READ_FLASH)==0 )
   {
      Sleep(100);
      nRet = SerialRead(hSerial, (char*)abyInfo, &dwSize, 1000);
      if( nRet==CL_ERR_SUCCESS )
      {
         if( _strcmpi(pI->szSignature,VINF_SIGNATURE)==0 )
            memcpy(pInfo,pI,sizeof(VENDOR_INFO));
         else nRet = CL_ERR_GENERIC;
      }
   }
   return nRet;
}
```

The routine reads the structure and validates it with a comparison between the *szSignature* string and the “VINF” constant. After the read of the structure, the user can also read the firmware version with the routine below.

```
void CCLinkPort::GetFirmwareVersions(SER_HANDLE hSerial,
unsigned long& nVer1, unsigned long& nVer2)
{
   unsigned char byData = 0;
   nVer1 = 128;
   nVer2 = 0;
   if( ReadRegister(hSerial,SR_VERSION, &byData)==CL_ERR_SUCCESS
)
      nVer1 = byData;
   byData = 0;
   if( ReadRegister(hSerial,SR_VERSION+1,
&byData)==CL_ERR_SUCCESS )
      nVer2 = byData;
   if(nVer2==0) nVer2 = 1;
}
```

The nVer1 value is usually 128; the nVer2 value may change and may be used to detect which initialization values have to be sent to the camera.

4.4. Init the camera

After the camera detection (model, sensor, serial number) the user should send the initialization sequence to the camera. The steps are shown in the Open routine in the CLinkCam.cpp file.

- Send Reset Command (see the following topics).
- Set Camera Initialization for the configuration of some camera internal registers.
- Set Default values of configuration parameters (Rate, exposure, gain).

4.4.1. M3 camera

The routine can be called only once. It sets three registers with values retrieved from the VENDOR_INFO structure.

```
void CCLinkPort::SetM3Registers(SER_HANDLE hSerial, unsigned
long nReg1, unsigned long nReg2, unsigned long nReg3)
{
   WriteRegister(hSerial,CR_RP1,(unsigned char)(nReg1&0xFF));
   WriteRegister(hSerial,CR_RP2,(unsigned char)(nReg2&0xFF));
   WriteRegister(hSerial,CR_RP3,(unsigned char)(nReg3&0xFF));
}
```

4.4.2. M5 camera

The routine initializes the camera internal timing. The timing sequence changes with different firmware and it should be sent each time the camera is reset.

```
void CCLinkPort::SetM5Registers(SER_HANDLE hSerial, unsigned
long nFwVersion, unsigned long nSnsModel)
{
  unsigned short awTim1[] = { 0x0803, 0x0FFF, 0x0803, 0x0000, 0x0003
};
  unsigned short awTim2[] = { 0x0803, 0x08FF, 0x0F81, 0x0000, 0x0001
};
  unsigned char
abyVal[]={0,100,170,190,10,160,255,2,255,255,200,200};
  unsigned long nRegAM40 = 0x0322;
  unsigned short d, *pwTim;
  int i;

  pwTim = nFwVersion>10 ? awTim2 : awTim1;

  for(i=0;i<5;i++)
  {
     d = pwTim[i];
     WriteRegister(hSerial,(CR_TIMING+2*i),d&0xFF);
     WriteRegister(hSerial,(CR_TIMING+2*i+1),(d>>8)&0xFF);
  }

  // write AM40 registers
  WriteRegisterBlock(hSerial,CR_SP_COMM_BUFF,&nRegAM40, 4);
  WriteRegister(hSerial, CR_SP_COMM, CR_SP_COMM_SET_SREG);

  if(nSnsModel==MV_SM_ORION_II)
  {
     // write sensor registers
     for(i=0;i<12;i++)
        WriteRegister(hSerial,(CR_M5_REG_START+i),abyVal[i]);
  }
}
```

4.5. Write Period and Exposure

The procedure for the configuration of the camera period and exposure are listed below.

- Convert the **exposure** from microseconds into camera internal units: US2Steps() routine in CLinkCam.cpp file.

- Convert the **period** from microseconds into camera internal units and correct the value.

```
unsigned long CCLinkCamera::ComputePeriodSteps(unsigned long
nPeriodUS)
{
   unsigned long nSteps =
m_Ser.US2Steps(m_Cfg.nClock,m_Cfg.nExpSteps,nPeriodUS);
   if(m_Cfg.nCamModel==MV_CM_MS_M3) nSteps -= 0;
   else
   {
      if(m_Cfg.nSnsModel==MV_SM_ORION_II) nSteps -= 25;
      else nSteps = nSteps - (m_Cfg.nFwVersion>10 ? 70 : 22);
   }
   return nSteps;
}
```

- If the exposure mode is **double**, compute the read out time with the number of rows and camera parameters read from the VENDOR_INFO structure (extra rows, RCC and clock). Subtract the read out from the period value.

  If the firmware version is larger than 17, the register 0x4C should be configured. The value is computed when the rate or the exposure changes and it is used to compensate the difference of intensity with low rates.

```
void CCLinkCamera::SetPeriodAndExposure()
{
   unsigned long nPer = m_Cfg.nPeriodStp;
   unsigned long nExp = m_Cfg.nExpStp;
   unsigned long nRows = m_Cfg.nRoiY1 - m_Cfg.nRoiYo + 1;
   unsigned long nRo = READ_OUT(m_Cfg.nRCC,
(nRows+m_Cfg.nExtraRows), m_Cfg.nExpSteps);

   if(m_Cfg.nExpMode==MV_EM_DOUBLE)
      nPer -= nRo;

   m_Ser.WritePeriodAndExposure(m_hSer,nPer,nExp);
   if(m_Cfg.nFwVersion>17)
   {
      int nSafeGap = 32;
      int nTX_R = (m_Cfg.nCamModel==MV_CM_MS_M5) ? 200 : 8;
      int n = (nPer - nExp)*8 - nROT;
      int nROT = (nRows + 1)*m_Cfg.nRCC + nTX_R;
      n -= nROT + nSafeGap;
      if( m_Cfg.nCamModel==MV_CM_MS_M3 || n < 0 ) n = -1;
      m_Ser.WriteRegister4C(m_hSer,(unsigned long)n);
   }
```

- Write the period and exposure registers (see below)

```
void CCLinkPort::WritePeriodAndExposure(SER_HANDLE hSerial,
unsigned long nPer, unsigned long nExp)
{
   unsigned long nData;
   int i;

   if(nExp>(nPer-2)) nExp = nPer-2;

   // exposure
   nData = (nPer - 3) - (nExp - 1);
   for( i=0; i<4; i++ )
   {
      WriteRegister(hSerial,(unsigned char)(CR_EXPOSURE_TIME+i),
(unsigned char)(nData&0xff) );
      nData >>= 8;
   }
   // period
   nData = nPer - 3;
   for( i=0; i<4; i++ )
   {
      WriteRegister(hSerial,(unsigned
char)(CR_PERIOD+i),(unsigned char)(nData&0xff));
      nData >>= 8;
   }
}
```

- If the firmware version is 18 or above, Write the register 0x4C (see below)

```
void CCLinkPort::WriteRegister4C(SER_HANDLE hSerial, unsigned
long nReg)
{
   unsigned long i,nVal;
   nVal = nReg;
   for(i=0; i<3; i++)
   {
      WriteRegister(hSerial, (0x4C+i), (nVal&0xff));
      nVal >>= 8;
   }
}
```

4.6. Write sensor gain

Sensor gain is controlled by a full set of DAC voltages that are sent to the camera. The VENDOR_INFO structure (that should be read before any other operation) contains 4 sets of DAC voltages, one for each sensor gain.

When the sensor gain changes the corresponding set of DAC values should be sent to the camera. The number of DAC values is 16 for M5 and 10 for M3. M3 camera has an additional value that is used for the overlap/non overlap mode. For further explanation please see the topic 4.9.

```
int CCLinkPort::WriteDACs(SER_HANDLE hSerial, unsigned long *pDAC, int
nIsM5)
{
   unsigned long nPtr=0, nDACCode;
   __int64 nData,nMask;
   unsigned long i, j, nx, ny, sh, nBits,nSize, nDACsRef;
   unsigned char nDataBit;

   if( nIsM5 ) { nx = 8; ny = 2; nSize=16; nDACsRef = 5000; }
   else { nx =  2; ny = 2; nSize=10; nDACsRef = 3000; }
   nBits = 16*ny;
   nMask = ((__int64)1)<<(nBits-1);

   for( i=0; i<8; i++)
   {
      nData = 0;
      for( j=0, nData=0, sh=0; j<ny; j++ )
      {
         if( j==(ny-1) && i>=nx ) nDACCode = 0;
         else nDACCode = (1024 * pDAC[i + 8*j]) / nDACsRef;
         if (nDACCode > 1023) nDACCode = 1023;
         nData += (__int64)(((i + 1)<<12) + (nDACCode << 2)) << sh;
         sh += 16;
      }
      // 2 values
      WriteRegister(hSerial,CR_DACS,0);
      WriteRegister(hSerial,CR_DACS,CB_DACS_CS);
      // 32 x 3 = 96 values (or 48 x 3 values)
      for (j = 0; j < nBits; j++)
      {
         nDataBit = (nData & nMask) ? CB_DACS_DATA : 0;
         nData <<= 1;
         WriteRegister(hSerial,CR_DACS, CB_DACS_CS + nDataBit);
         WriteRegister(hSerial,CR_DACS, CB_DACS_CS + nDataBit +
CB_DACS_CLOCK);
         WriteRegister(hSerial,CR_DACS, CB_DACS_CS + nDataBit);
      }
      // 2 values
      WriteRegister(hSerial,CR_DACS, CB_DACS_CS);
      WriteRegister(hSerial,CR_DACS, 0);
   }
   return CL_ERR_SUCCESS;
}
```

4.7. Region Of Interest (ROI)

4.7.1. Simple ROI

M cameras have vertical windowing so the region of interest is configured by setting the start and stop sensor lines (see the routine below)

```
// ROI (only the rows can be configured)
void CCLinkPort::WriteRoi(SER_HANDLE hSerial, unsigned long nYo,
unsigned long nY1)
{
  // ROI first row
  WriteRegister(hSerial,CR_ROI_FIRST_ROW, (unsigned char)(nYo&0xff));
  WriteRegister(hSerial,CR_ROI_FIRST_ROW+1,(unsigned
char)((nYo>>8)&0xff));
  // ROI last row
  WriteRegister(hSerial,CR_ROI_LAST_ROW, (unsigned char)(nY1&0xff));
  WriteRegister(hSerial,CR_ROI_LAST_ROW+1, (unsigned
char)((nY1>>8)&0xff));
}
```

4.7.2. Multiple ROI (MROI)

Multiple ROI correspond to select which rows of the sensor will be activated to grab an image. The rows can be selected without any limit.

Once the rows are selected (CM_MR_ADD_LO and CM_MR_ADD_HI), the user must set the registers of regular ROI with the values of 0 and N-1, where N is the total number of activated rows (see below).

```
// Multiple ROI (every row can be selected or deselected)
// pbyRowsMap is an array of bool values (0:row is off, 1:row is on)
void CCLinkPort::WriteMultiRoi(SER_HANDLE hSerial, unsigned char
*pbyRowsMap, unsigned long nSensorHgt)
{
   unsigned long i,nSize;
   // set addresses and compute size
   WriteRegister(hSerial,CR_MR_RESET,1);
   nSize = 0;
   for(i=0;i<nSensorHgt;i++)
   {
      if( pbyRowsMap[i] )
      {
         WriteRegister(hSerial,CR_MR_ADD_LO,(unsigned char)i);
         WriteRegister(hSerial,CR_MR_ADD_HI,(unsigned char)(i>>8));
         nSize++;
      }
   }
   if(nSize)
      WriteRoi(hSerial,0,nSize-1);
}
```

4.8. Other parameters

Other parameters that can be set are:

Exposure mode: WriteExpMode() routine in CLinkPort.cpp file.

Pixel Gain: WritePixelGain() routine in CLinkPort.cpp file.

“Sync In” configuration: WriteSyncInCfg() routine in CLinkPort.cpp file.

“Trigger In” configuration: WriteTrigInCfg() routine in CLinkPort.cpp file.

4.9. Send Commands

The commands that can be sent to the camera are listed in the SendCommand() routine in the CLinkCam.cpp file.

```
MV_ERROR CCLinkCamera::SendCommand(MV_COMMAND nCmdKey)
{
   switch(nCmdKey)
   {
   case MVCMD_RECORD:
      if(m_Cfg.nCamModel==MV_CM_MS_M3) CheckDACsM3();
      m_Ser.SendCmdStartStreaming(m_hSer);
      break;
   case MVCMD_STOP:
      m_Ser.SendCmdStopStreaming(m_hSer);
      break;
   case MVCMD_TRIGGER:
      m_Ser.SendCmdTrigger(m_hSer);
      break;
   case MVCMD_RESET:
      m_Ser.SendCmdReset(m_hSer);
      if(m_Cfg.nCamModel==MV_CM_MS_M5)

   m_Ser.SetM5Registers(m_hSer,m_Cfg.nFwVer,m_Cfg.nSnsModel);
      break;

   default:
      return MV_E_NOT_SUPPORTED;
   }
   return MV_SUCCESS;
}
```

Record (Start Streaming): before starting streaming the user should check if the camera is in overlap or non overlap mode (see next topic).

Stop (Stop Streaming): a specific command stops any camera streaming.

Trigger: send a command to issue a software trigger to the camera.

Reset: if the camera is M5, after the reset the user should send the timing initialization sequence.

4.10. Check Overlap and non overlap (M3 camera)

M3 camera operates in **Overlap** mode when the exposure and the acquisition period values satisfy the formula below:

$$T_{exp} + T_{ro} > T$$

Where:

T_{exp} = exposure time

T_{ro} = Readout time. It's the inverse of the maximum rate (at full resolution is about 5.88 ms).

T = period (inverse of the acquisition rate).

If the formula above is not true, the camera is in "**non-overlap**" mode. Before starting streaming, the user should check if the camera is in overlap or non overlap mode and change the value of one of the DAC voltages.

- anDAC[2] = value for non overlap mode.
- anDAC[10] = value for overlap mode.

The procedure is shown in the routine below.

```
void CCLinkCamera::CheckDACsM3()
{
   unsigned long nVref3=0, *pDAC;
   unsigned long anDACs[NMAXDACS];
   int nIdx;

   if(m_Cfg.nGain==0) pDAC = m_Cfg.anDACs0;
   else if(m_Cfg.nGain==1) pDAC = m_Cfg.anDACs1;
   else if(m_Cfg.nGain==2) pDAC = m_Cfg.anDACs2;
   else if(m_Cfg.nGain==3) pDAC = m_Cfg.anDACs3;
   // DAC[2] may change if the camera is in overlap or non
overlap
   if(IsOverlap())
   {
      nVref3 = pDAC[m_Cfg.nDACsCnt];
      nIdx = 1;
   }
   else
   {
      nVref3 = pDAC[2];
      nIdx = 0;
   }
   // if Vref3 has changed, send the DAC array to the camera
   if(nVref3!=m_nCurrVref3)
   {
      memcpy(anDACs,pDAC,NMAXDACS*sizeof(unsigned long));
      anDACs[2]  = nVref3;

   m_Ser.WriteDACs(m_hSer,anDACs,m_Cfg.nCamModel==MV_CM_MS_M5);
      m_nCurrVref3 = nVref3;
   }
}
```

4.11. How to compute the maximum frame rate

The routine below shows how to compute the value of the minimum acquisition period (i.e. the inverse of the maximum frame rate). The minimum period is approximately equal to the read out time and it depends on some internal camera parameters (clock, RCC and extra rows) and some configuration parameters (number of rows in the ROI).

If the ROI is simple the number of rows is calculated as the difference between start row and stop row. If the ROI is multiple the number of rows is the total number of active rows (see below)

```
// Calculate the number of active rows
int CCLinkCamera::ComputeRowsCount()
{
  int i,nRows=0;
  if( m_Cfg.nRoiMode==MV_ROI_MULTI )
  {
      for(i=0;i<(int)m_Cfg.nSnsHgt;i++)
      {
          if( m_Cfg.abyRoiTbl[i] ) nRows++;
      }
  }
  else nRows = m_Cfg.nRoiY1 - m_Cfg.nRoiYo + 1;
  return nRows;
}
```

```
// Calculate the inverse of the maximum frame rate
unsigned long CCLinkCamera::ComputeMinPeriod()
{
  unsigned long nRows = m ComputeRowsCount();
  double dRows = (double)(nRows+m_Cfg.nExtraRows);
  double dRCC = (double)(m_Cfg.nRCC*1000);
  double dDel = (8000000000./(double)m_Cfg.nClock);
  double dClk = ((double)m_Cfg.nClock)/1000000.;
  double dt;
  // dt is computed in ns
  if(m_Cfg.nExpMode==MV_EM_DOUBLE)
     dt = (2*dRCC*dRows)/dClk + 3*dDel;
  else
     dt = (dRCC*dRows)/dClk + 2*dDel;
  dt = (dt*100.5)/100.;
  // convert to us
  return ((unsigned long)dt)/1000;
}
```

5. Appendix

5.1. Appendix A - Return Codes

The following table shows the values of the codes returned by the MV APIs. The values can be found in the **MVX_API.h** header file in the **Include** subdirectory.

Code	Value	Notes
MV_SUCCESS	0	OK – No errors
MV_E_GENERIC_ERROR	1	Generic Error
MV_E_INVALID_ARGUMENTS	2	Invalid function arguments
MV_E_INVALID_CAMERA_ID	3	Invalid camera ID used in MVOpenCamera. The ID is retrieved from the MVEnumCameras routine
MV_E_CAM_ALREADY_OPEN	4	Cannot open the camera because it's already open.
MV_E_INVALID_HANDLE	5	Invalid MV_HANDLE camera handle
MV_E_NOT_SUPPORTED	6	The function is not supported
MV_E_INVALID_VALUE	7	Invalid parameter value
MV_E_NO_LINE	8	The image does not contain the shutter line
MV_E_NO_DATA	9	No correction data is available
MV_E_BUF_TOO_SMALL	10	The buffer is too small

5.2. Appendix B – Camera Info Parameters

The following table shows the values and a brief description of the parameters that can be retrieved by calling the MVGetCameraInfo routine. The numeric values of the parameters can be found in the **MVX_API.h** header file in the **Include** subdirectory.

Parameter	Description
MVI_CAMERA_ID	Camera ID (see MV_ENUMITEM structure in MVX_API.h)
MVI_CAMERA_MODEL	Camera Model (see MV_CAM_TYPE in MVX_API.h)
MVI_COLOR	The camera is color (0: monochrome – 1:color)
MVI_SERIAL	The camera serial number (10 digits decimal value)
MVI_REVISION	The camera revision
MVI_FG_TYPE	The Camera Link™ frame grabber model
MVI_SNS _WIDTH	The sensor width [pixels]
MVI_SNS _HEIGHT	The sensor Height [pixels]
MVI_FW_VERSION	The camera firmware version
MVI_CAL_FILE	The camera calibration file is installed
MVI_MULTI_ROI	The multiple ROI is supported
MVI_SNS_MODEL	Sensor Model (see MV_SENSOR_MODEL in MVX_API.h)
MVI_EXTRA_ROWS	The camera extra rows (rows that should be removed from the image)
MVI_EXTRA_COLS	The camera extra columns (columns that should be removed from the image)
MVI_CFA_PATTERN	The sensor color filter array pattern (GRBG, BGGR, RGGB or GBRG)

5.3. Appendix C – Camera Parameters

The following table shows the values and a brief description of the parameters that can be read and written in the camera. The numeric values of the parameters can be found in the **MVX_API.h** header file in the **Include** subdirectory.

Parameter	Rd/Write	Description
MVP_EXPOSURE	R/W	Camera exposure in microseconds [µs]
MVP_PERIOD	R/W	Acquisition period in microseconds [µs]
MVP_GAIN	R/W	Camera gain (0 to 3)
MVP_REC_MODE	R/W	Recording mode (0: normal, 1:circular)
MVP_SYNCIN_CFG	R/W	Sync In configuration (internal, ext pulse/edge - high/low)
MVP_ROI_Y_MIN	R/W	Y minimum ROI coordinate (simple ROI mode)
MVP_ROI_Y_MAX	R/W	Y maximum ROI coordinate (simple ROI mode)
MVP_ROI_MODE	R/W	ROI mode (simple or multiple)
MVP_ROI_TABLE	R/W	ROI table (multiple ROI mode)
MVP_EXP_MODE	R/W	Exposure mode (single or double)
MVP_PIXEL_GAIN	R/W	Pixel Gain (upper, middle, lower)
MVP_SHUTTER_LINE	R	The position of the shutter line (if the image does not have it, the MVGetParameter routine returns MV_E_NO_LINE)
MVP_BKG_INDEX	R	The index of the current background buffer for image correction
MVP_PSC_INDEX	R	The index of the current pixel sensitivity (PSC) buffer for image correction
MVP_TRIGIN_CFG	R/W	The trigger in configuration parameter
MVP_POST_TRIG_N	R/W	The number of frame to stream after the trigger
MVP_SYS_BAUDRATE	R/W	The serial port baud rate (system parameter)

5.4. Appendix D – Camera Commands

The following table shows the values and a brief description of the command that can be sent to the camera. The numeric values of the parameters can be found in the **MVX_API.h** header file in the **Include** subdirectory. “Lo Param” and “Hi Param” are ignored. They have been introduced for future use.

Parameter	Value	Lo Param	Hi Param	Description
MVCMD_RECORD	0	Not used	Not used	Start recording/streaming
MVCMD_STOP	1	Not used	Not used	Stop recording/streaming
MVCMD_TRIGGER	2	Not used	Not used	Send a software trigger
MVCMD_RESET	3	Not used	Not used	Reset the camera

5.5. Appendix E – Data types

This appendix describes the data types defined in the **MVX_API.h** header file.

5.5.1. MV_BAUD_RATE

The MV_BAUD_RATE enumerates the serial port baud rates

- **MV_BAUDRATE_9600**: 9600 pbs.
- **MV_BAUDRATE_19200**: 19200 pbs.
- **MV_BAUDRATE_38400**: 38400 pbs.
- **MV_BAUDRATE_57600**: 57600 pbs.
- **MV_BAUDRATE_115200**: 115200 pbs.
- **MV_BAUDRATE_230400**: 230400 pbs.
- **MV_BAUDRATE_460800**: 460800 pbs.
- **MV_BAUDRATE_921600**: 921600 pbs.

5.5.2. MV_CAM_MODEL

The MV_CAM_MODEL type enumerates the camera models.

- **MV_CM_UNKNOWN**: Unknown camera model
- **MV_CM_MS_M3**: MotionScope M3.
- **MV_CM_MS_M5**: MotionScope M5.

5.5.3. MV_SNS_MODEL

The MV_CAM_MODEL type enumerates the camera models.

- **MV_SM_UNKNOWN**: Unknown sensor model
- **MV_SM_SIRIUS**: Sirius sensor (M3).
- **MV_SM_ORION**: Orion sensor (M5).
- **MV_SM_ORION_II**: Orion II sensor (M5).

5.5.4. MV_CFA_PATTERN

The MV_CFA_PATTERN type enumerates the color filter array pattern in color sensors.

- **MV_CFA_GRBG**: GRBG pattern.
- **MV_CFA_BGGR**: BGGR pattern.
- **MV_CFA_RGGB**: RGGB pattern.
- **MV_CFA_GBRG**: GBRG pattern.

5.5.5. MV_FG_TYPE

The MV_FG_TYPE type enumerates the frame grabber models.

- **MV_FG_COR_X64CL**: Dalsa-Coreco X64 Xcelera-CL PX4.
- **MV_FG_NIPCIE1429**: National Instruments PCIe-1429.
- **MV_FG_MATROX_S_H**: Matrox Solios/Helios.
- **MV_FG_EPIXCI_E4**: Epix PIXCI E4.
- **MV_FG_BF_KARBON**: Bitflow Karbon-CL.
- **MV_FG_SSOFT_ME4**: Silicon Software ME4.
- **MV_FG_EDT_PCIE8**: EDT PCI-E8 DV C-Link.

5.5.6. MV_REC_MODE

The MV_REC_MODE enumerates the camera record modes:

- **MV_RM_NORMAL**: normal acquisition mode.
- **MV_RM_CIRCULAR**: circular acquisition mode.

5.5.7. MV_GAIN

The MV_GAIN enumerates the camera sensor gain:

- **MV_GAIN_0**: no gain (-3 dB).
- **MV_GAIN_1**: gain 1 (0 dB).
- **MV_GAIN_2**: gain 2 (+3 dB).
- **MV_GAIN_3**: gain 3 (+6 dB).

5.5.8. MV_SYNCIN_CFG

The MV_SYNCIN_CFG enumerates the configuration of the Sync In:

- **MV_SIC_INTERNAL**: internal frame rate acquisition.
- **MV_SIC_EXT_EDGE_HI**: external, exposure starts on edge, active high.
- **MV_SIC_ EXT_EDGE_LO**: external, exposure starts on edge, active low.
- **MV_SIC_ EXT_PULSE_HI**: external, exposure integrated over pulse, active high.
- **MV_SIC_ EXT_PULSE_LO**: external, exposure integrated over pulse, active low.

5.5.9. MV_TRIGIN_CFG

The MV_TRIGIN_CFG enumerates the configuration of the Trigger In:

- **MV_TIC_EDGE_HI**: the trigger starts on edge, active high.
- **MV_TIC_EDGE_LO**: the trigger starts on edge, active low.
- **MV_TIC_SWC**: the trigger starts on Switch Closure.
- **MV_TIC_DISABLE**: the trigger is disabled.

5.5.10. MV_ROI_MODE

The MV_ROI_MODE enumerates the ROI modes:

- **MV_ROI_SIMPLE**: simple ROI mode.
- **MV_ROI_MULTI**: multiple ROI mode.

5.5.11. MV_EXP_MODE

The MV_EXP_MODE enumerates the exposure modes:

- **MV_EM_SINGLE**: single exposure.
- **MV_EM_DOUBLE**: double exposure.

5.5.12. MV_PIXEL_GAIN

The MV_PIXEL_GAIN enumerates the camera pixel gain:

- **MV_PG_UPPER**: upper bits.
- **MV_PG_MIDDLE**: middle bits.
- **MV_PG_LOWER**: lower bits.

5.5.13. MV_ERROR

The MV_ERROR enumerates the return codes. See Appendix A.

5.5.14. MV_INFO

The MV_INFO enumerates the camera information index. See Appendix B.

5.5.15. MV_PARAM

The MV_PARAM enumerates the camera parameters. See Appendix C.

5.5.16. MV_COMMAND

The MV_COMMAND enumerates the camera commands. See Appendix D.

5.6. Appendix F – Structures

This appendix describes the structures defined in the **MVX_API.h** header file.

5.6.1. MV_ENUMITEM

The MV_ENUMITEM structure contains information about a camera. It must be used in the camera enumeration procedure with the MVEnumCameras routine.

```
typedef struct
{
     unsigned long cbSize;
     unsigned long bIsOpen;

     unsigned long nCamID;
     unsigned long nCamModel;
     unsigned long nSnsModel;
     unsigned long nColor;
     unsigned long nSerial;
     unsigned long nRevision;
     unsigned long nFGType;
     unsigned long nSnsWid;
     unsigned long nSnsHgt;
     unsigned long nFwVersion;
     unsigned long nCFAPattern;
     char szPortID[L_PORT_ID];

} MV_ENUMITEM, *PMV_ENUMITEM;
```

Members

cbSize

It specifies the size of the MV_ENUMITEM structure.

bIsOpen

It specifies whether the camera is currently open or not.

nCamID

It specifies the ID which identifies the camera. The user must use this camera ID to open the camera with MVOpenCamera.

nCamModel

It specifies the camera model (M3 or M5).

nSnsModel

It specifies the sensor model (Sirius, Orion, and Orion II).

nColor

It specifies whether the camera is color or not.

nSerial

It specifies the camera serial number (10 decimal digits value).

nRevision

It specifies the camera revision number.

nFGType

It specifies the Camera Link Frame Grabber model.

nSnsWid

It specifies the sensor width in pixels.

nSnsHgt

It specifies the sensor height in pixels.

nFwVersion

It specifies the camera firmware version.

nCFAPattern

It specifies the color filter array pattern (color sensors only).

szPortID

it specifies the serial port identifier string.

5.7. Appendix G – Camera Link Directory

The camera link directory is the folder that contains the camera link serial dynamic linking libraries.

The path to the directory is specified in the following registry key:

HKEY_LOCAL_MACHINE\Software\CameraLink

The path is specified as a value named "**CLSerialPath**" with type string REG_SZ.

Each frame grabber manufacturer should install its own camera link serial DLL in the path specified by the value above. If the above key does not exist, they should create it and add the directory value.